



Introduction to Visual Computing

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Visual Computing

Domain: Visual computing is the computer science discipline that deals with images and 3D objects.

This course: Introduce some of the basic principles and techniques in this domain that are used in most image related fields such as computer vision, computer graphics and medical imaging.
In particular:

- What is an image ?
- How is it formed ?
- How is it represented ?
- What information to extract and how ?

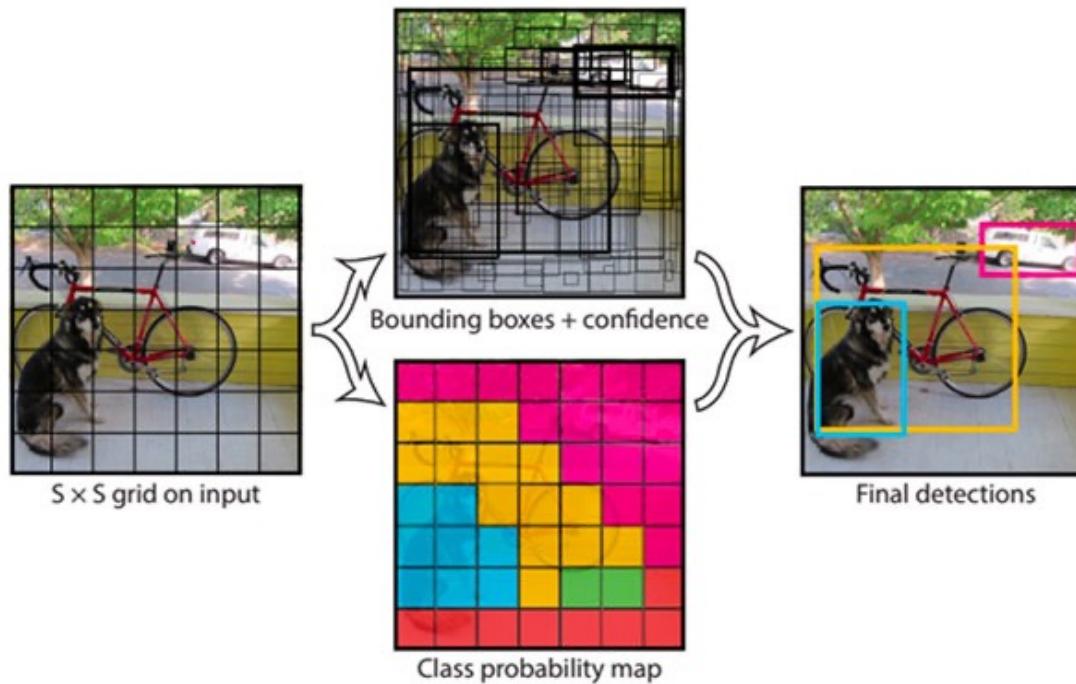
Some Applications



Source: Researchgate

Building panoramas by stitching images

Some Applications



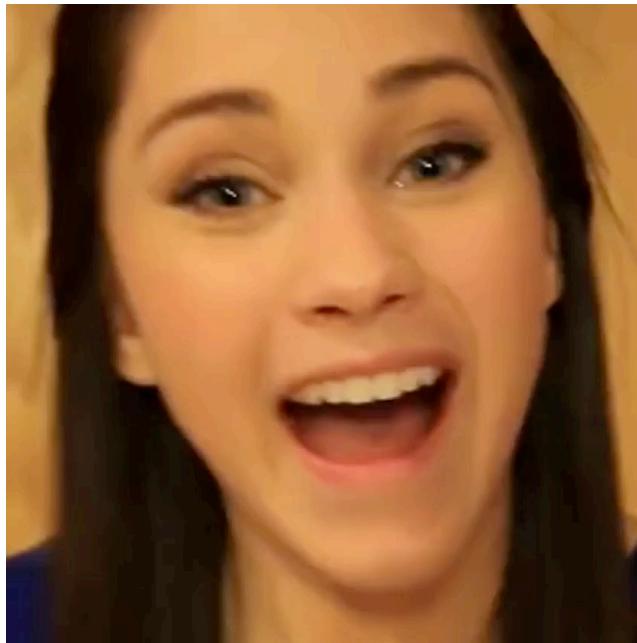
You Only Look Once (YOLO) object detection with OpenCV

Some Applications



Augmented reality

Some Applications



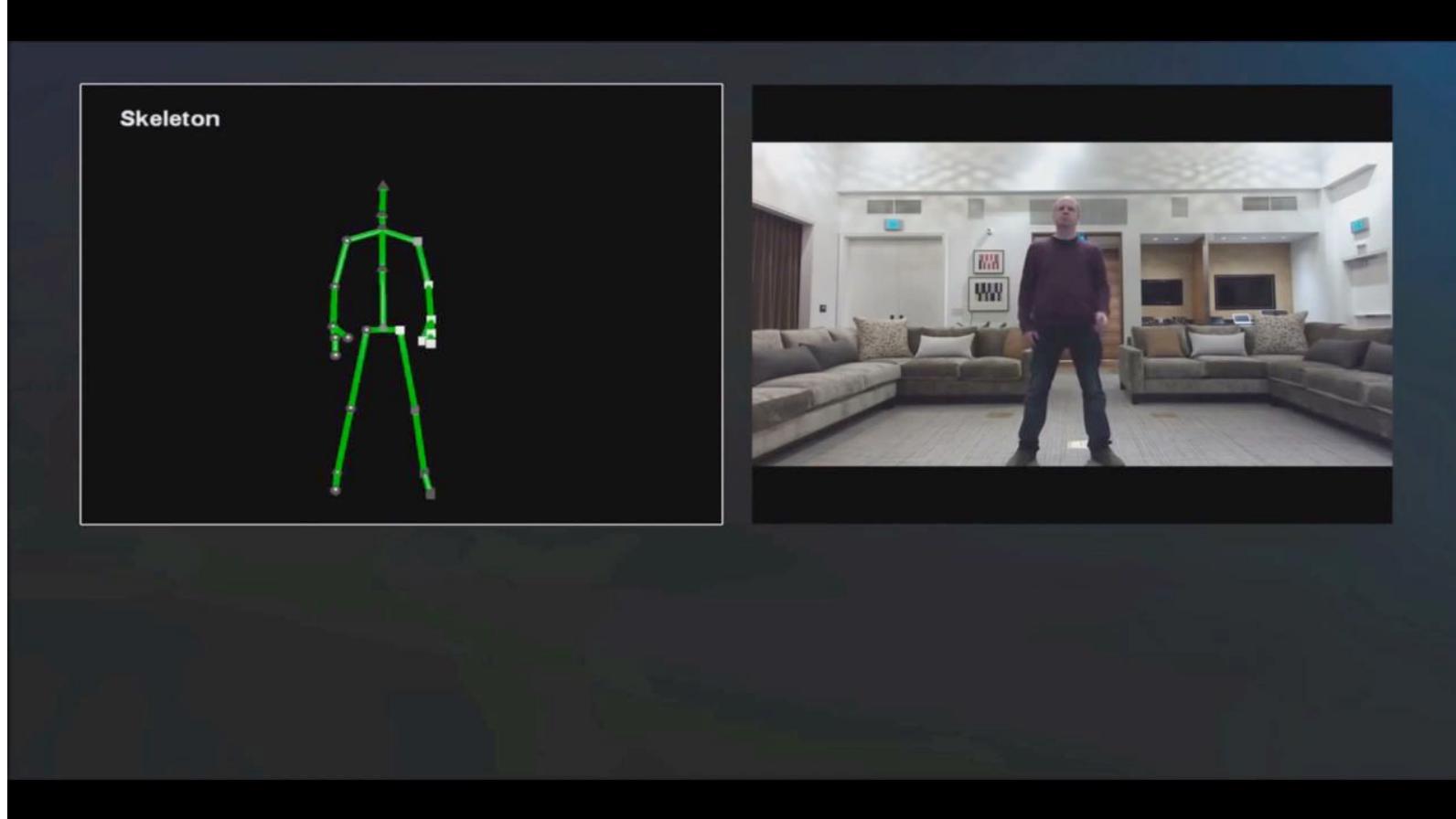
Single Image 3D Face Reconstruction

Some Applications



@Microsoft, High-Quality Streamable Free-Viewpoint Video, Siggraph'15
3D-4D Modeling

Some Applications



Microsoft Kinect: human skeleton poses (+orientations) from depth images

What is an image ?

Humans: a set of visual information with semantic meanings such as people, objects, landscapes, graphics, etc.

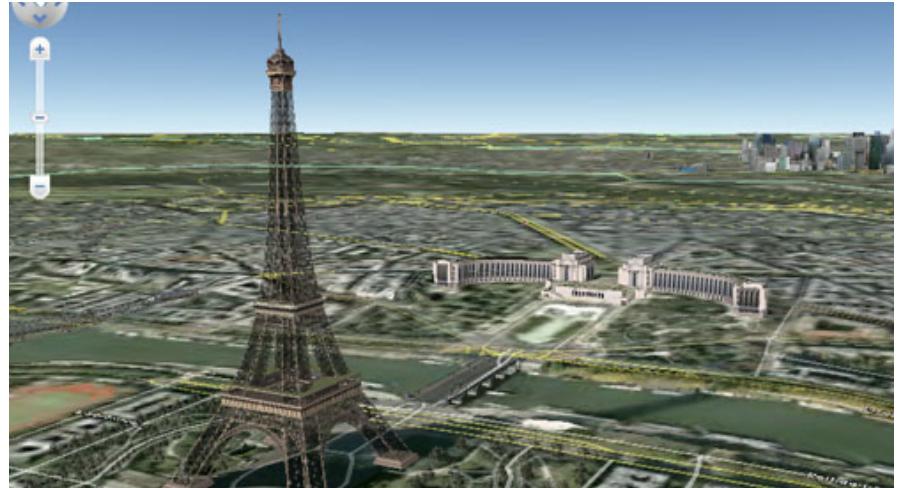
Math.: a 2D discrete signal $s(x,y)$ that represents the intensity of light onto an image plane.

Computers: an array of numbers that can be read from/written to/ a file, manipulated by programs and sent to the video card to be displayed as color intensities.

What is an image ?



Real image (captured)



Synthetic image (generated)

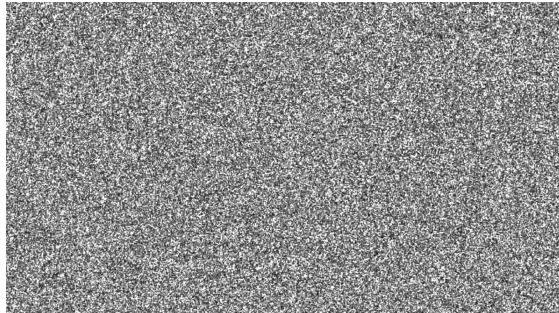
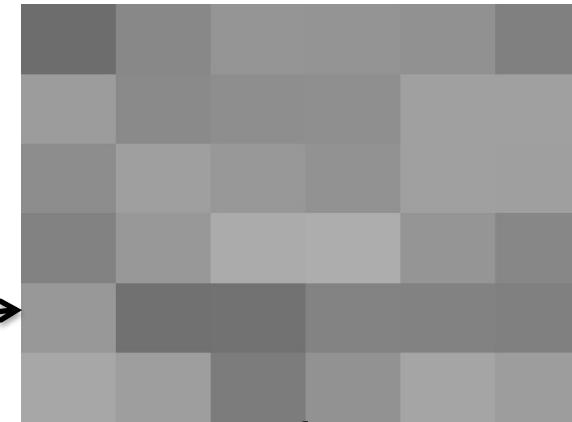
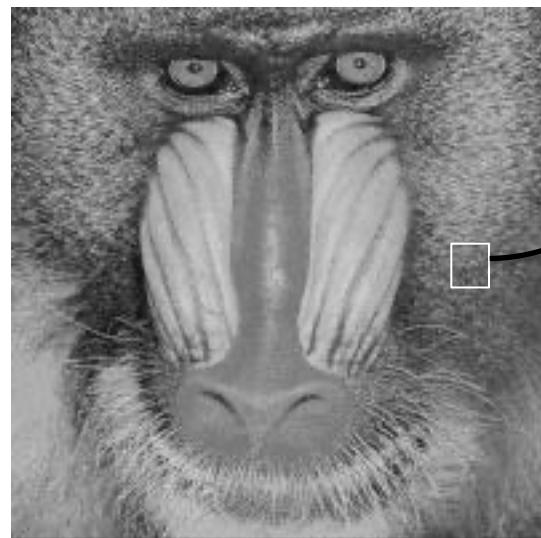
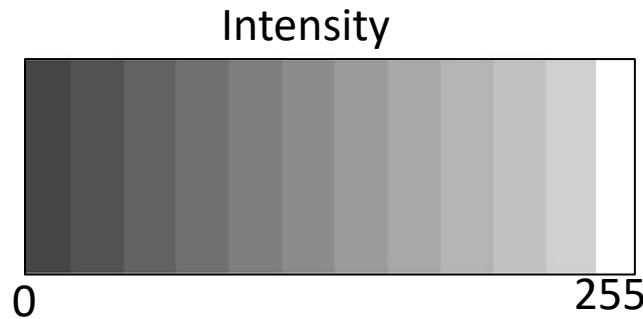


Image noise

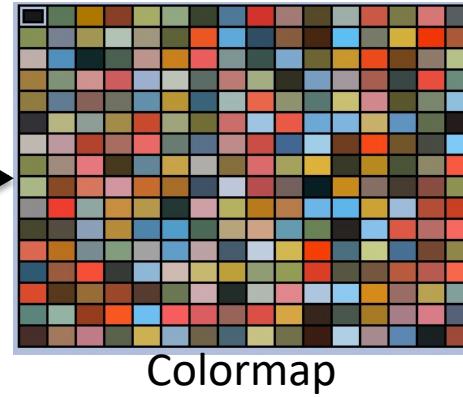
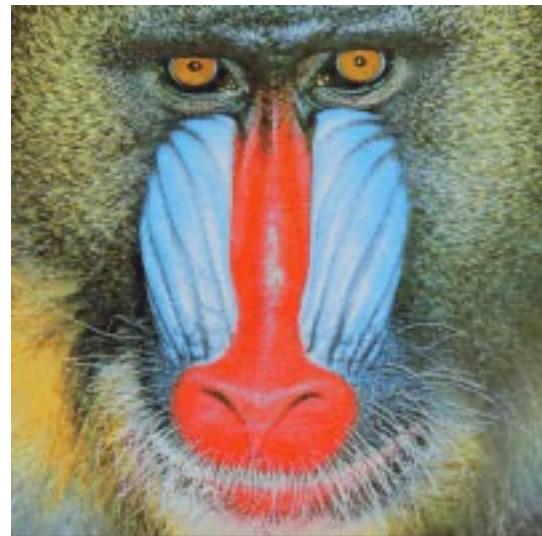
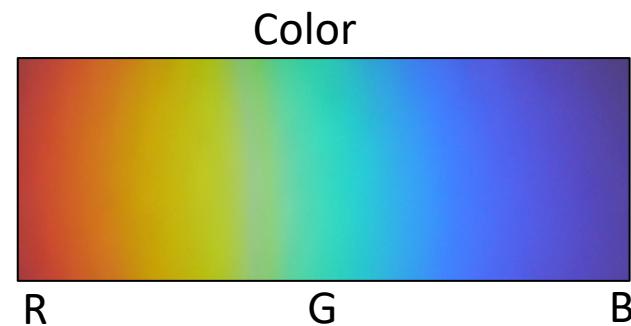
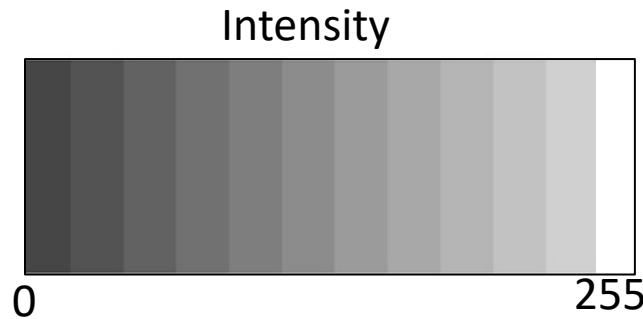
Random variations of intensities (image noise) appear in real images. They result from the acquisition process : e.g. imprecisions in the measures.

What is an image ?



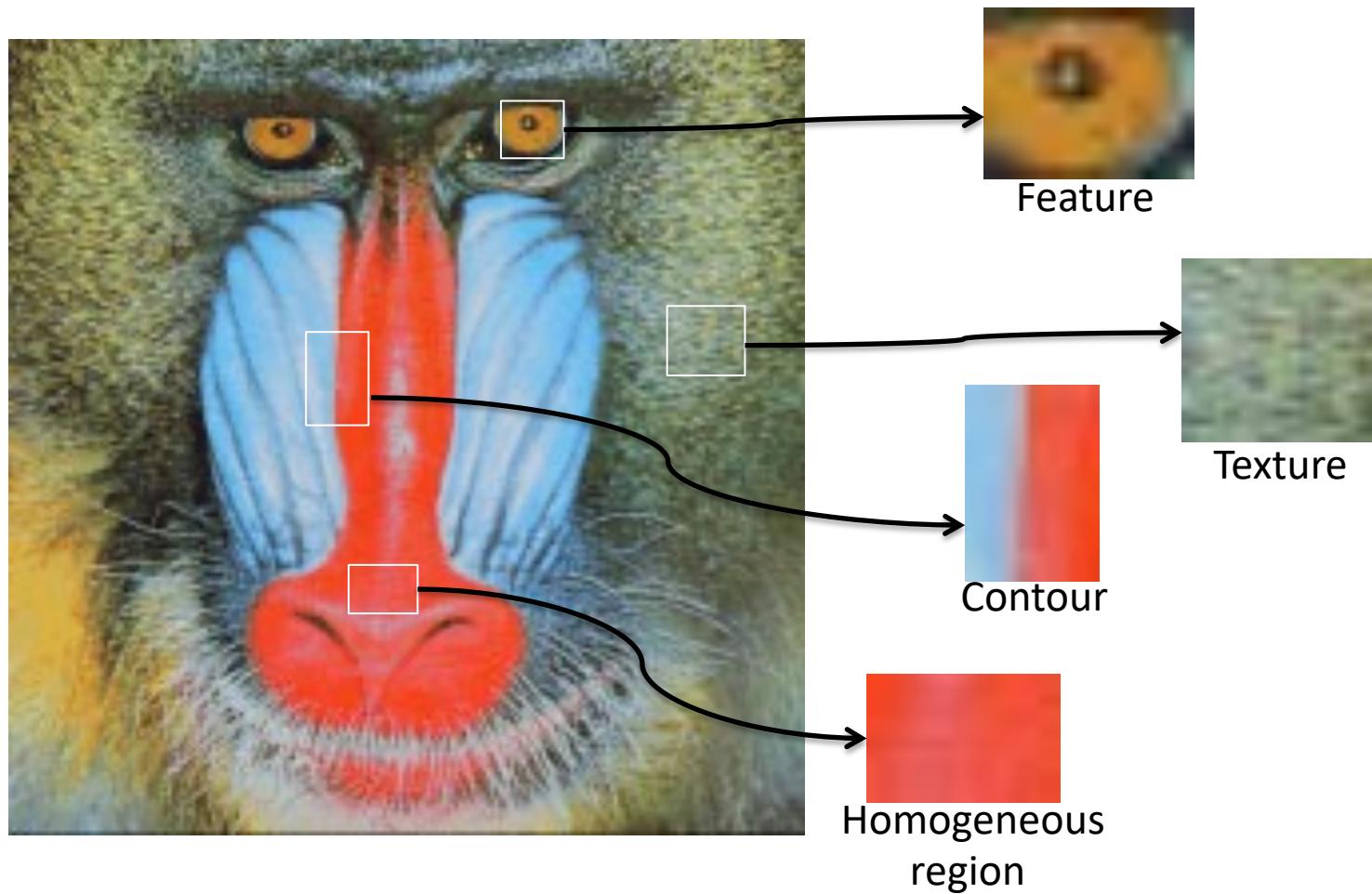
109	136	149	148	145	128
156	138	142	143	160	160
141	159	152	146	160	159
130	152	171	173	149	135
152	113	114	131	130	128
167	158	124	146	165	157

What is an image ?



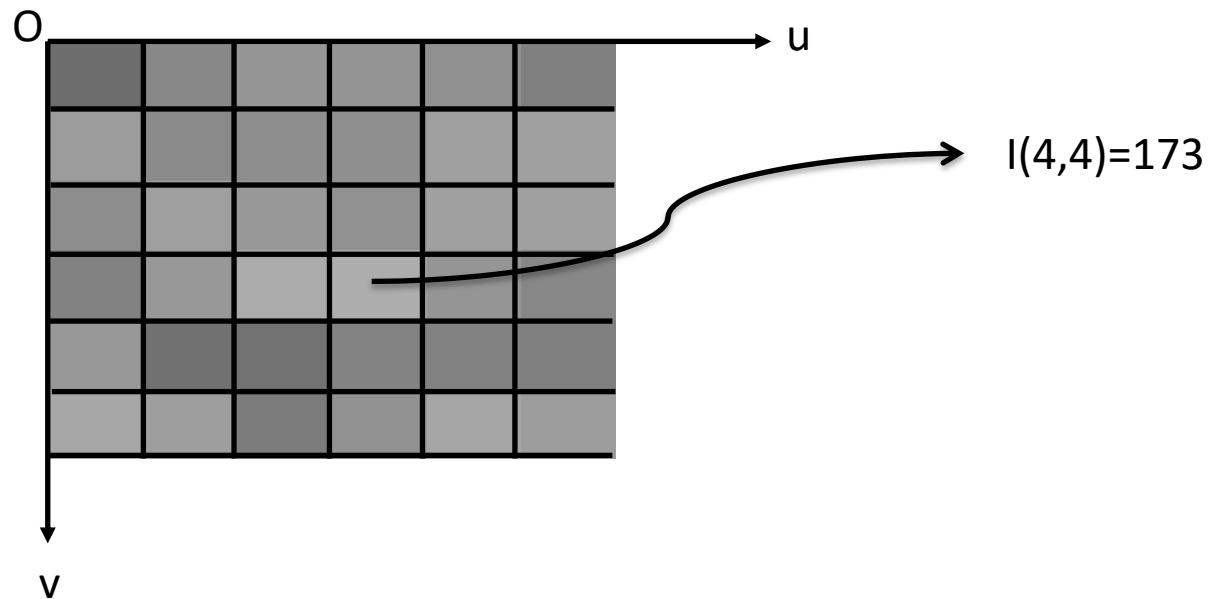
Colormap

What is an image ?



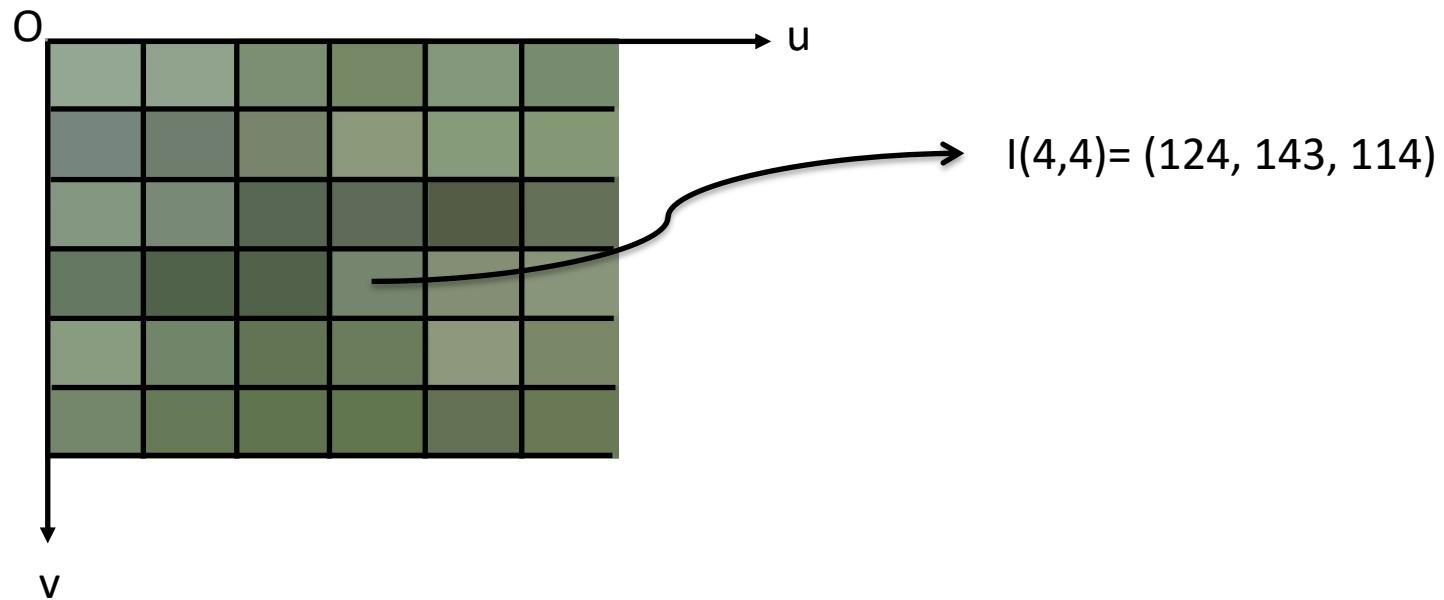
What is an image ?

A digital image is an array of pixels (picture elements) with coordinates (u,v) and intensity values $I(u,v)$.



What is an image ?

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What is an image ?



Binary



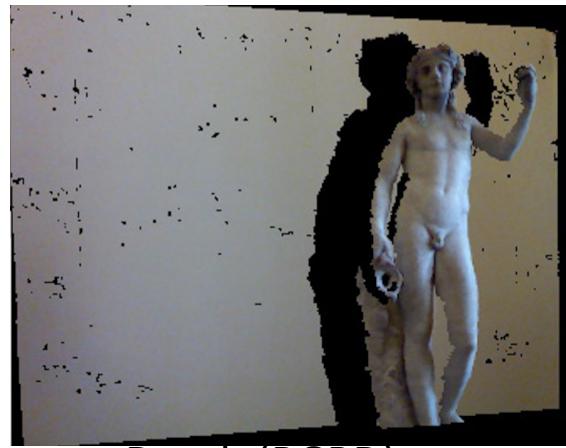
Greyscale



Color (RGB)



+Transparency (RGBA)

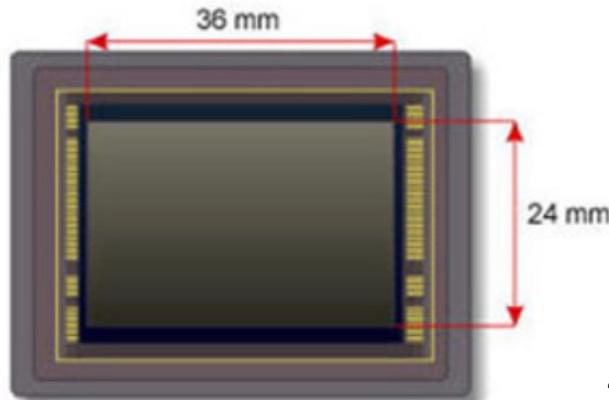


+Depth (RGBD)

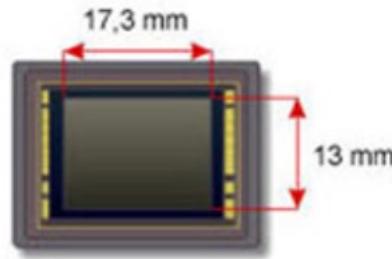
What is an image ?

Image capture: sensors that measure light.

- Resolution: number of photosites on the sensor ≠ pixels
- Sizes: dimensions can be very diverse but bigger is better



Full frame: e.g. Canon 6D



4/3: e.g. Panasonic lumix



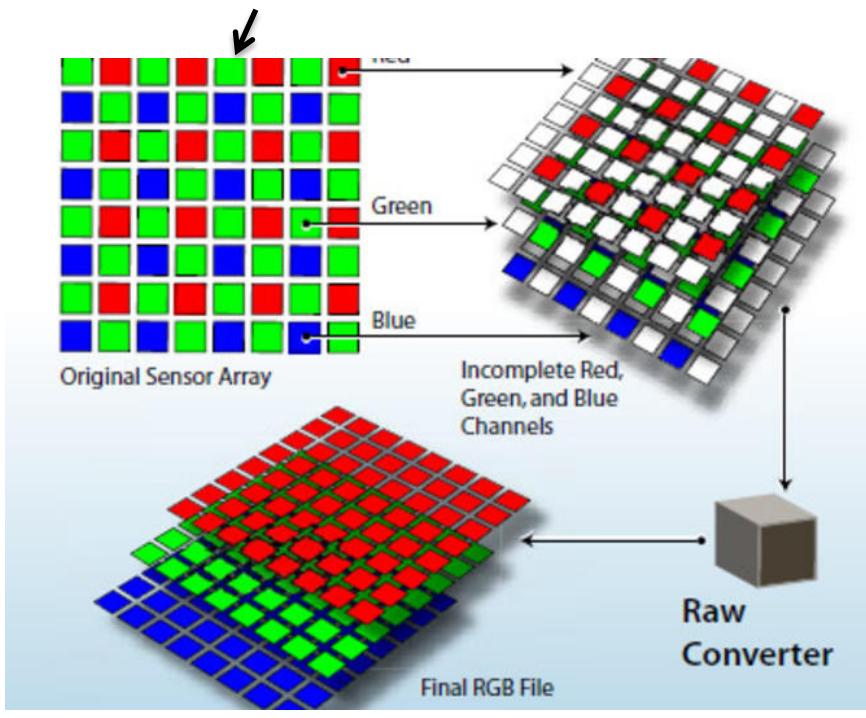
Mobile phones

Source: cnet.com

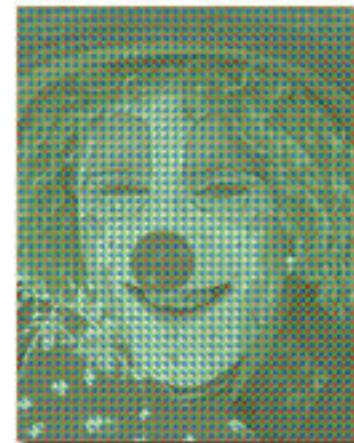
What is an image ?

Image capture: sensors that measure light.

Bayer color filter array (mosaic)



Source cnet.com



Bayer raw image



Bayer decoding /
demosaicing

Source: olympusmicro.com

What is an image ?

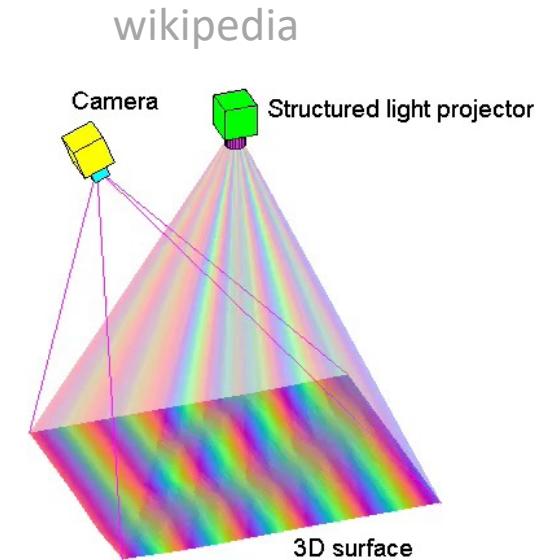
Image capture: depth images.

Time of Flight (ToF) sensors: measure light travel time from source (camera) to 3D scene and back (e.g. kinect V2).



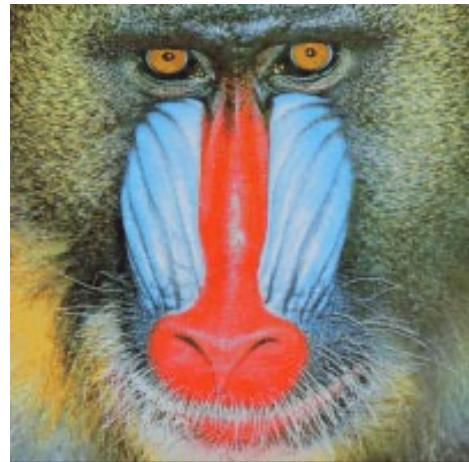
Stereo rig: 2 cameras and matching based triangulation

Structured light systems: a known (usually infrared) pattern is projected and observed by a camera with known position with respect to the projector (e.g. kinect V1).

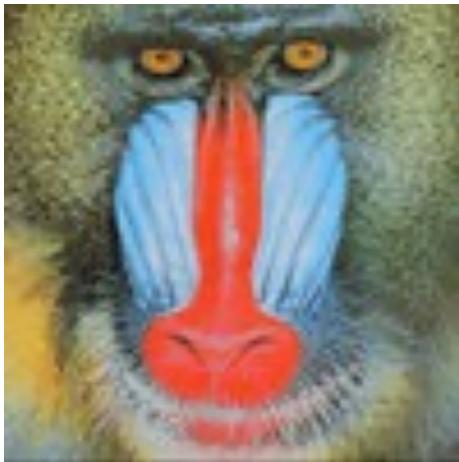


What is an image ?

Image resolution and color quantification



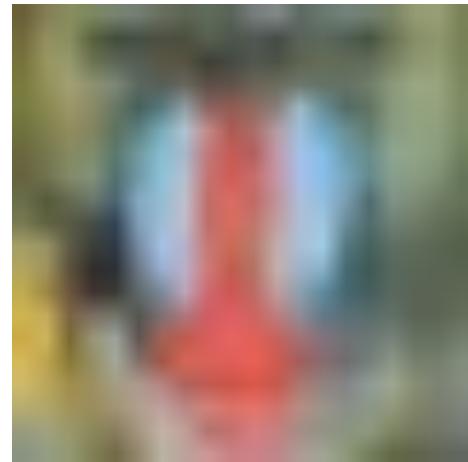
200x200, full colors



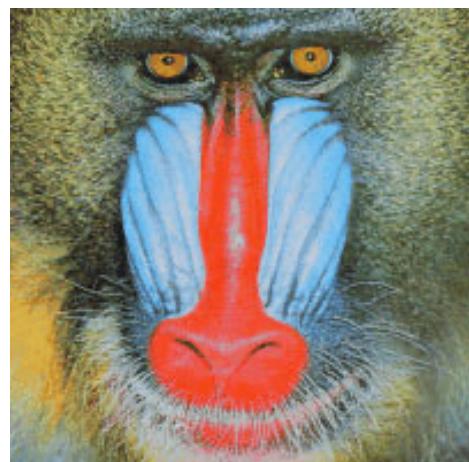
100x100



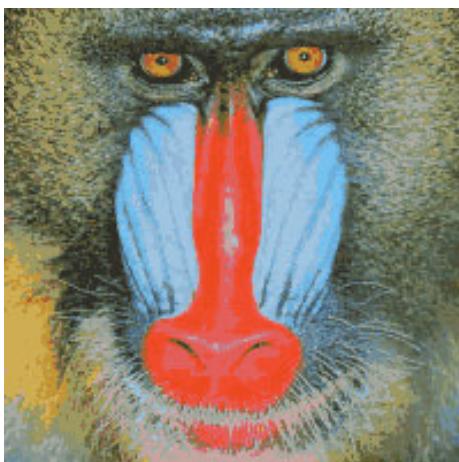
50x50



20x20



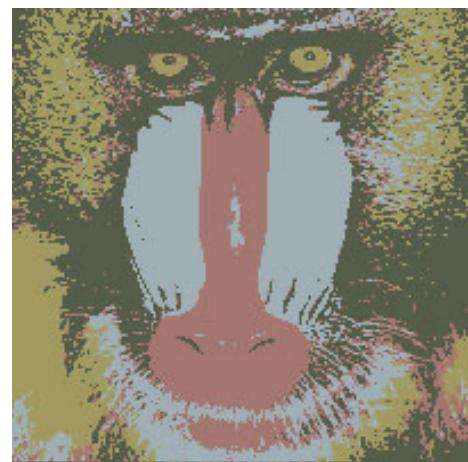
200x200, 256 colors



64



8



4

What is an image ?

Pixel Information

Intensity encoding

8 bits (sometimes 16 bits) -> value range [0..255]

Encoding: unsigned int, (float)

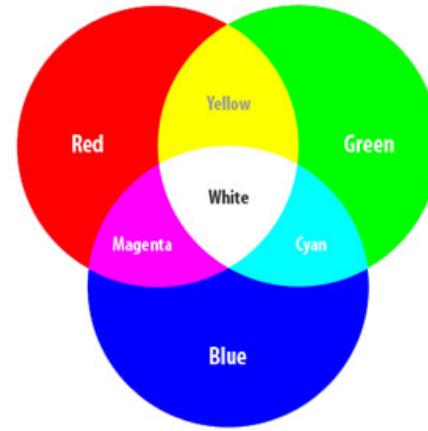
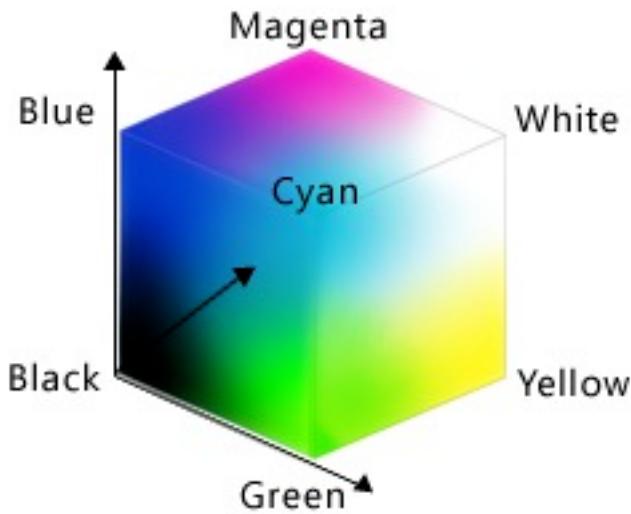
Color encoding

- RGB: Displays, Image processing
- CMY: Printers
- HSL: more intuitive color model for human perception
- Many others

What is an image ?

Pixel Information

RGB space

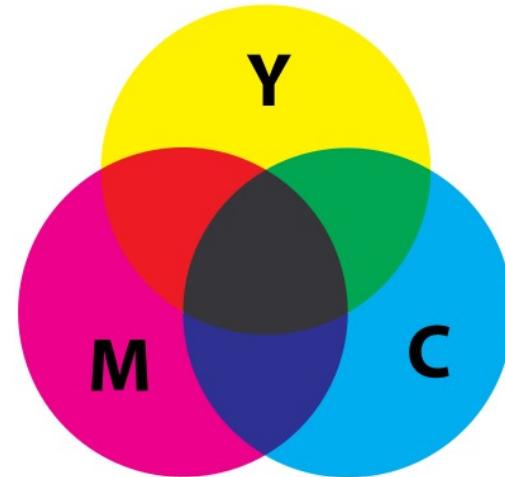
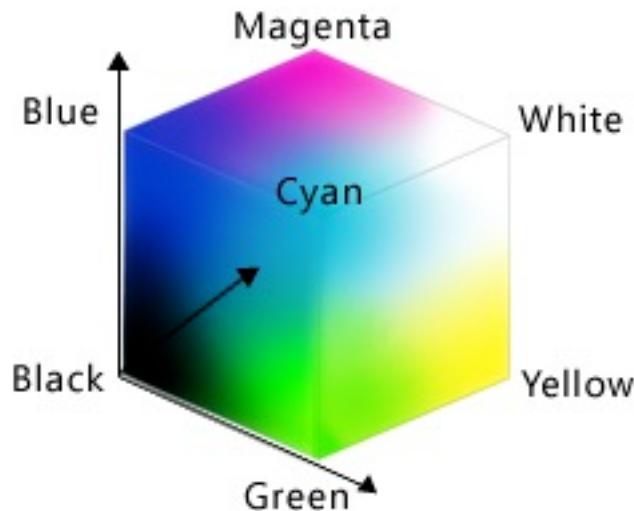


- A color is a point within the RGB cube.
- Additive color model (displays): from black add RGB components to get a given color.
- Colors accessible by this model depend on the red, green and blue primary colors
- Examples: Yellow = $(1,1,0)$; Blue = $(0,0,1)$, Black = $(0,0,0)$.

What is an image ?

Pixel Information

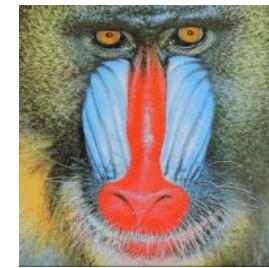
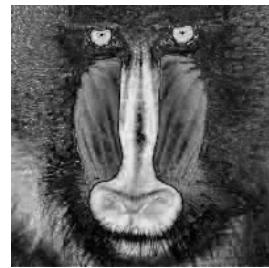
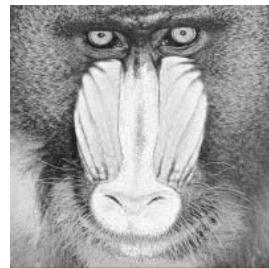
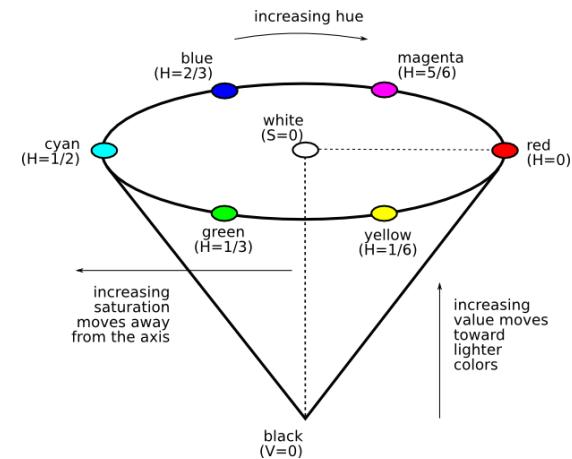
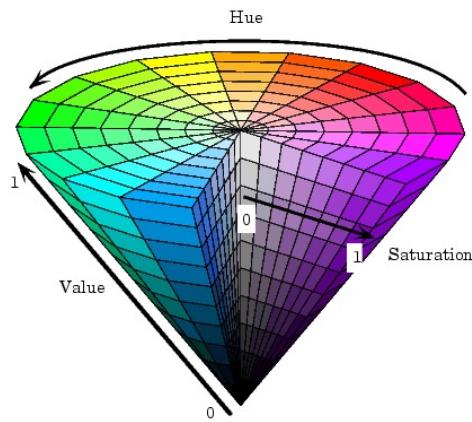
CMY space



- Subtractive color model (printers): from white subtract CMY components.
- Printers usually consider the 4 component CMYK model (k=black).
- No easy conversion with RGB since the primary colors are different.
- Examples: Yellow = (0,0,1); Blue = (1,1,0), Black = (1,1,1).

What is an image ?

HSV (Hue, Saturation, Value) space



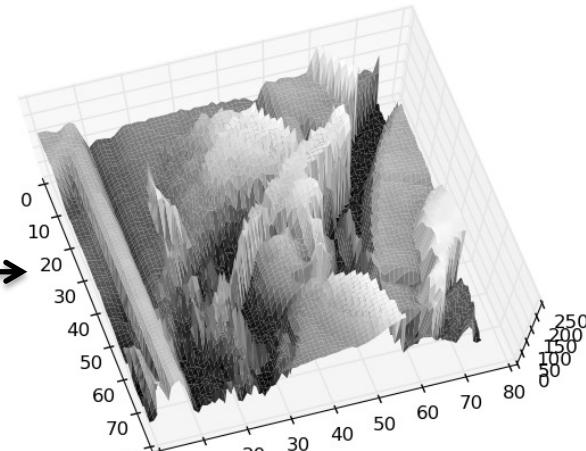
- Hue: colors vary from red, through yellow, green, cyan, blue, and magenta,
- Saturation: colors (hues) vary from unsaturated (shades of gray) to fully saturated (no white component).
- Value, or brightness: the corresponding colors become increasingly brighter

What is an image ?

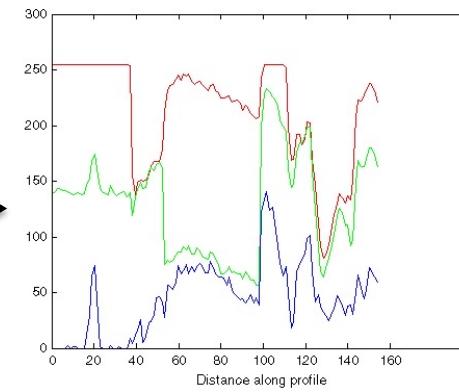
Pixel information as functions over the 2D image domain



Greyscale intensity function



Intensity profiles



- Enable mathematical operations: derivatives, gradients !
- Implicit continuous assumption.

Image Analysis



Different processing levels (usually successive):

- Low level: e.g. feature, edge extraction; segmentation.
- High level: e.g. 3D modeling, recognition.

Elements involved:

- Image primitives: pixels, edges, features.
- Photometric properties: intensities, colors
- Geometric properties: cameras, motions.

Image Synthesis



- Geometric Modeling;
- Light and illumination Modeling;
- Material properties;
- Animations;
- Rendering.

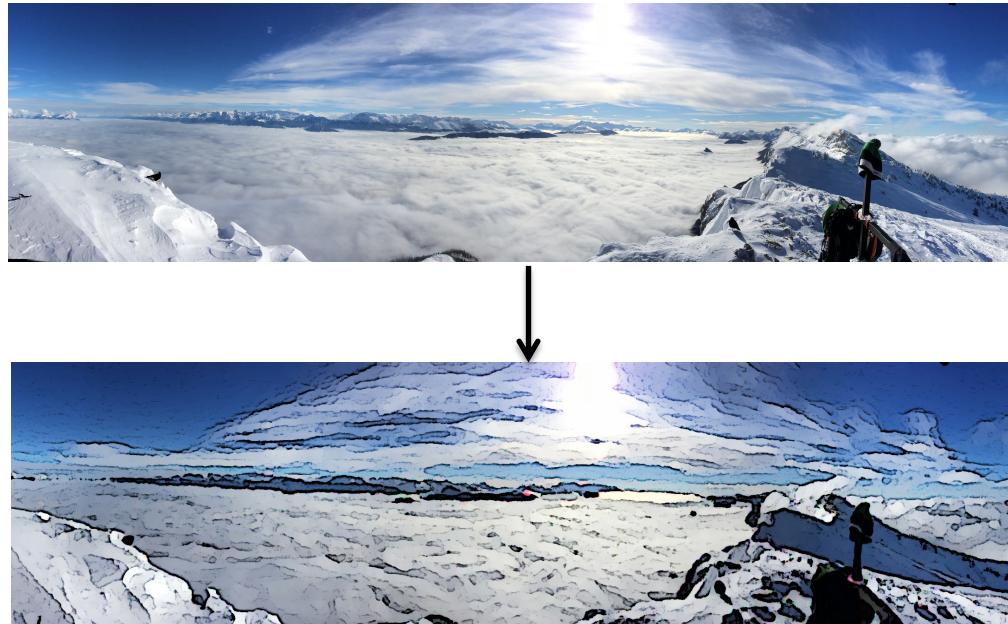


-> M1Mosig 2nd Semester

Course Outline

1. Introduction (lecture)
2. File Format (Practical work)
3. Image Processing (lecture)
4. Filtering, histograms (Practical work)
5. Features (Lecture)
6. Harris corner detector (Practical Work)
7. Segmentation (Lecture)
8. K-means (Practical work)
9. Image Formation (Lecture)
10. Image Recognition (Practical work)

Image Processing



- Histogram modifications: color transformations..;
- Filtering: blurring, sharpening, ..;

Image Features

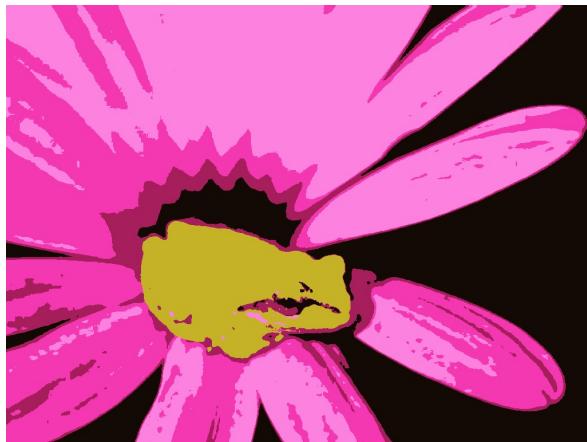


Edge detection



Harris feature detection

Image Segmentation



K-means clustering with K=6 and K=3.

Image Formation

From 3D scene to 2D images

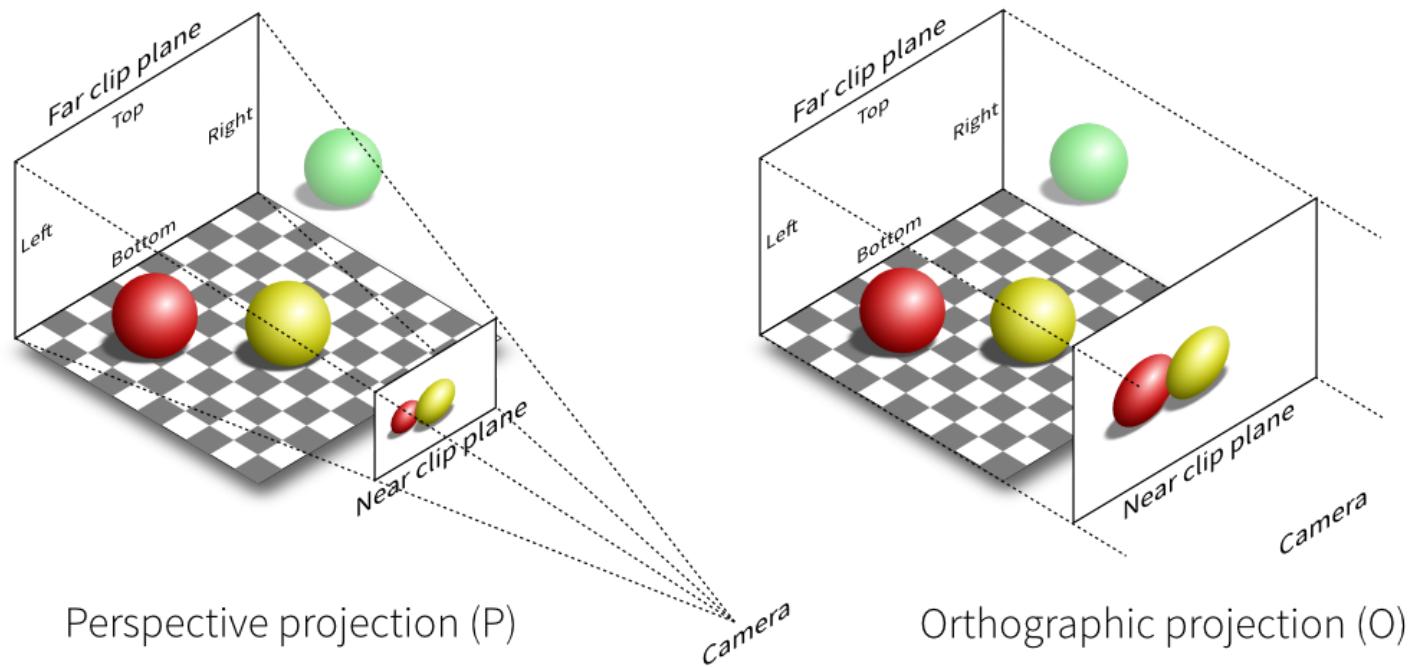


Image Formation

Stereovision

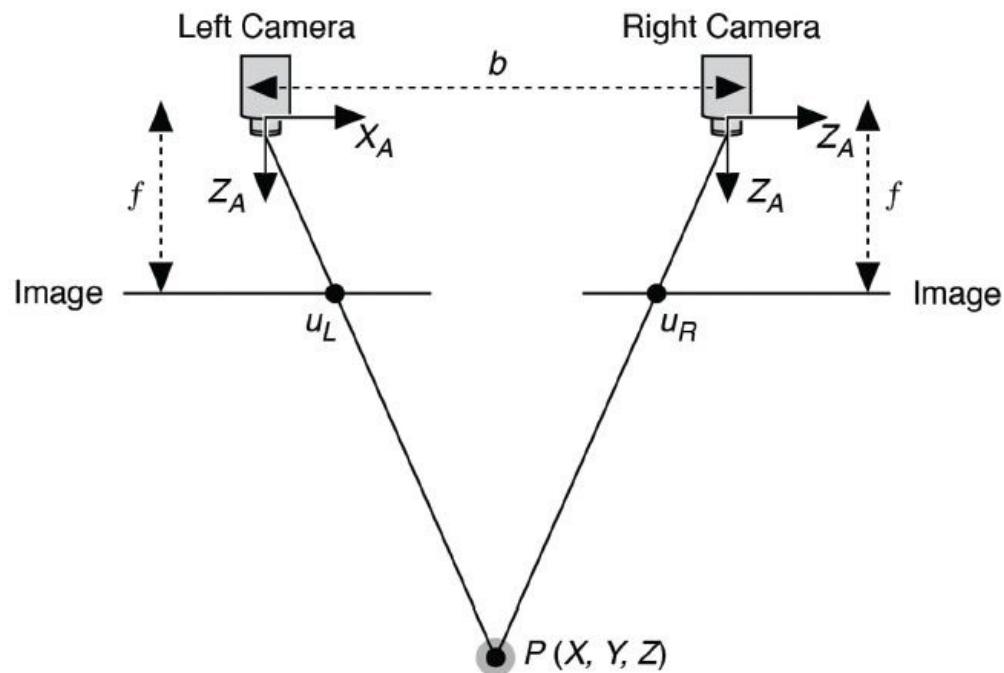


Image Formation

3D Displays



Autostereoscopic display



HMD

Stereoscopic displays: 2 views with fixed viewpoint; Usually with glasses.

Autostereoscopic: > 2 views with fixed viewpoint; No glasses.

HMD: 2 views with viewpoints that depend on the user location/orientation,
-> full 3D experience.